Plant Sociology 60(1) 2023, 13–23 | DOI 10.3897/pls2023601/02 *Topical Collection: "Biodiversity management and conservation"*

PENSOFT

Società Italiana di Scienza della Vegetazione (SISV)

Vegetation features of two vascular plant species presumed extinct and recently rediscovered in the natural habitat of community interest 8320 from Mt. Vesuvius, Italy

Adriano Stinca[1]

1 *Department of Environmental, Biological and Pharmaceutical Sciences and Technologies, University of Campania Luigi Vanvitelli, I-81100 Caserta, Italy*

Corresponding author: Adriano Stinca (adriano.stinca@unicampania.it)

Subject editor: Carmelo Maria Musarella ♦ **Received** 10 November 2022 ♦ **Accepted** 23 February 2023 ♦ **Published** 12 April 2023

Abstract

This paper illustrates the results of a survey aimed at deepening knowledge on vegetation in which *Festuca lachenalii* and *Ophioglossum lusitanicum* were recently discovery on Mt. Vesuvius (Italy) after about 200 and 150 years from the last observation, respectively. Both species were previously thought to be locally extinct. These noteworthy microphytes are rare and poorly documented species within their global distribution range. They were found within a habitat of community interest (Habitats Directive 92/43/EEC), where they are subject to extensive anthropogenic impact and require urgent actions for their *in situ* conservation.

Keywords

Festuca lachenalii; Habitats Directive 92/43/EEC; herbaria; native plants; *Ophioglossum lusitanicum*; phytosociological relevés; pioneer plant communities; plant conservation; plant extinction; vascular flora

Introduction

The high plant diversity of the Mediterranean Basin hotspot can be related to the heterogeneity of climatic conditions and the variety of geomorphological formations. Although the greatest floristic richness of endemic plants is observed on limestone soils (e.g., Conti et al. 2019; Musarella et al. 2020), in volcanic areas plants adapt to different ecological conditions that may often represent the limits for their survival. For example, plants growing close to volcanoes have to cope not only with high atmospheric contamination above ground, but also with potentially toxic compounds in the rhizosphere (Baillie et al. 2018). Mt. Vesuvius is an active volcano with a long documented history of eruptions. It is a stratovolcano located in the eastern part of the Bay of Naples, along the Tyrrhenian coast of southern Italy. The eruptions that occurred in different historical periods have changed the landscape with a great impact also on its vegetation cover. This volcanic area is currently covered by pioneer plant communities on the pyroclastites and lavas, by mixed broadleaf forests, by monospecific and mixed coniferous vegetation and by shrublands. In addition, in the area extensive cultivated and urbanized areas are present (Ricciardi et al. 2016). Of these vegetation types, only the pioneer communities have been studied with a phytosociological approach by Agostini (1975), Mazzoleni et al. (1989), and Mazzoleni and Ricciardi (1993). The latter reported high lichen dominance on the lavas produced by the 1944 eruption, and an increasing presence of elements of *Tuberarietea guttatae* and *Thero-Brachypodietea* on the 1906 and 1858 lavas, respectively. Regarding the plant communities on pyroclastic slopes, Mazzoleni et al. (1989) only proposed a grouping with *Rumex scutatus* L. subsp. *scutatus*, *Scrophularia canina* L., and *Silene vulgaris* (Moench) Garcke subsp. *tenoreana* (Colla) Soldano & F.Conti. However, since we are dealing with processes of primary succession where the vegetation is rapidly evolving (Stinca et

Copyright *Adriano Stinca*. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

al. 2009), updated studies are necessary for their syntaxonomic classification. Much of the area is protected via the establishment of protected areas (Site of Community Importance IT8030036 "Vesuvio", Site of Community Importance IT8030021 "Monte Somma", Special Protection Area IT8030037 "Vesuvio e Monte Somma", and Vesuvius National Park). In accordance with the standard data forms of the abovementioned Natura 2000 sites and with recent updates (Tavilla et al. 2022), the following habitats of community interest (Habitats Directive 92/43/EEC) are reported: 8310 (Caves not open to the public), 8320 (Fields of lava and natural excavations), 9260 (*Castanea sativa* woods), 9540 (Mediterranean pine forests with endemic Mesogean pines), and 9340 (*Quercus ilex* and *Quercus rotundifolia* forests).

Regarding flora, although in Italy there is a long tradition of botanical investigations (Stinca et al. 2021), historically researchers have paid little attention to the study of the vascular flora of Vesuvius. The last comprehensive research on Vesuvian flora was published more than 30 years ago by Ricciardi et al. (1988): while they ascertained the occurrence of 610 species and subspecies, they also reported a high incidence of unconfirmed species, for some of which they declared probable local extinction, due to anthropogenic impact. Indeed, the Vesuvian area is one of the most densely populated areas in the world, with about three million inhabitants, with the consequence of considerable potential impact on flora and vegetation. Although recent field research and herbarium investigations have contributed to improve floristic knowledge (Stinca and Motti 2009, 2013; Stinca et al. 2012a, 2012b, 2013), contributing to the rediscovery of species considered locally extinct (Stinca 2017) and to reporting some new alien species for Europe (Stinca et al. 2014; Stinca 2020), the vascular flora of Vesuvius requires further investigation, also considering recent advances in plant systematics that have concerned the Mediterranean flora. Moreover, an exhaustive knowledge of the flora of this volcanic area is essential for the characterization of habitats of community interest and in their monitoring. This holds especially for nationally rare and poorly known habitats, such as the 8320 (Giusso del Galdo et al. 2016), also considering of the doubts that persist about the concepts of "typical", "diagnostic", "characteristic", and "keystone" species (Bonari et al. 2021).

In order to fill these knowledge gaps and to promote the conservation of native plant diversity, which is also important for human survival on Earth (Stinca 2022), in this paper I document the recent discovery of *Festuca lachenalii* (C.C.Gmel.) Spenn. (Poaceae) and *Ophioglossum lusitanicum* L. (Ophioglossaceae), a globally rare and noteworthy species for the Vesuvian flora, hitherto presumed extinct in the wild in this area. Some notes on their ecology, including a description of the plant communities, and conservation status are also provided.

Materials and methods

The study is based on field investigations carried out from 2014 to 2022. The collected specimens are preserved in the *Herbarium Austroitalicum* (code IT, acronym according to Thiers 2022) and were identified according to Flora d'Italia (Pignatti et al. 2017, 2019) and Flora Europaea (Stace 1980, Rothmaler et al. 1993). Geocoding of the Vesuvian localities was performed using a portable GPS device (GPS map 60CSx, Garmin, USA), calibrated to the UTM WGS84 reference system. The relevant literature was examined to detect previous indications of both species in the study area (Tenore 1831a, 1832; Pasquale 1869, Ricciardi et al. 1988).

For each species the following information is provided:

- currently accepted name according to the checklist of Italian vascular native flora (Bartolucci et al. 2018), with the indication of the place and year of publication previously verified;
- main synonyms with the indication of the place and year of publication previously verified;
- life form according to Flora d'Italia (Pignatti et al. 2017) and verified by *in situ* observations;
- global distribution and occurrence in Italy at regional level according to POWO (2022) and PFI (2022), respectively;
- data collected (specimens or observations), with details about the location and environment in Italian, according to the information on the specimen label data;
- previous reports in the study area;
- a description of the plant communities with phytosociological relevés carried out by applying the Braun-Blanquet (1932) method and literature analysis (Perrino et al. 2022) (the nomenclature of the taxa follows Bartolucci et al. 2018 and Galasso et al. 2018, while the nomenclature of the syntaxa follows Mucina et al. 2016);
- the main threats detected during field work and categorized according to the Threats Classification Scheme of the International Union for Conservation of Nature (IUCN 2022a);
- images taken in the study area regarding the new discoveries.

The data collected were used to draw up a distribution map with the opensource software QGIS (vers. 3.16, https://www.qgis.org/it/site/).

Results

Below I present the data regarding the rediscovery in the Vesuvian area of the investigated species.

FESTUCA LACHENALII (C.C.Gmel.) Spenn., Fl. Friburg. 3: 1050 (1829) – Figure 1.

≡ *Nardurus lachenalii* (C.C.Gmel.) Godr., Fl. Lorraine 3: 187 (1844).

≡ *Triticum lachenalii* C.C.Gmel., Fl. Bad. 1: 291 (1805).

≡ *Vulpia lachenalii* (C.C.Gmel.) Heynh., Nom. Bot. Hort.: 853 (1840).

= *Catapodium halleri* (Viv.) Rchb., Fl. Germ. Excurs.: 140 (1831).

= *Festuca festucoides* (Bertol.) Bech., Ber. Schweiz. Bot. Ges. 38: 153 (1929).

= *Micropyrum tenellum* (L.) Link, Linnaea 17: 398 (1844).

Life form: therophyta scaposa.

Global distribution: Euri-Mediterranean.

Italian distribution: Piemonte, Lombardia, Liguria, Emilia-Romagna (extinct), Toscana, Abruzzo, Campania (only historical record), Calabria, Sicily, Sardinia.

Specimens: Terzigno sui versanti SE del Gran Cono Vesuviano lungo la strada Matrone, 716 m a.s.l., piroclastiti, leg. et det. Adriano Stinca, 33T 453103-4518191, 21.04.2017 (IT); Ercolano nella Valle del Gigante, 902 m a.s.l., colata lavica del 1944, leg. et det. Adriano Stinca, 33T 451788-4520219, 23.05.2016 (IT); Ottaviano sui versanti SE del Gran Cono Vesuviano lungo la strada Matrone, 846 m a.s.l., arbusteto a *Genista etnensis* (Raf.) DC., leg. et det. Adriano Stinca, 33T 452579-4518503, 12.05.2015 (IT); Ottaviano sui versanti SE del Gran Cono Vesuviano lungo la strada Matrone, 798 m a.s.l., piroclastiti, leg. et det. Adriano Stinca, 33T 452458-4518149, 06.05.2015 (IT); Ottaviano sui versanti SE del Gran Cono Vesuviano lungo la strada Matrone, 798 m a.s.l., piroclastiti, leg. Adriano Stinca et Massimo Ricciardi, det. Adriano Stinca, 33T 452463-4518147, 30.08.2014 (IT); Ottaviano sui versanti ESE del Gran Cono Vesuviano, 1114 m a.s.l., piroclastiti, leg. Adriano Stinca et Giampiero Ciaschetti, det. Adriano Stinca, 33T 452155-4518930, 05.07.2014 (IT).

Observations: Torre del Greco sui versanti SW del Gran Cono Vesuviano, 1163 m a.s.l., piroclastiti, obs. et det. Adriano Stinca, 33T 451390-4518910, 22.06.2022; Ottaviano sui versanti SE del Gran Cono Vesuviano, 1141 m a.s.l., piroclastiti, obs. et det. Adriano Stinca, 33T 451982-4518811, 20.07.2021; Ottaviano sui versanti E del Gran Cono Vesuviano, 1001 m a.s.l., arbusteto a prevalenza di *Cytisus scoparius* (L.) Link subsp. *scoparius,* obs. et det. Adriano Stinca, 33T 452394-4519236, 18.05.2015.

Previous reports: Mortelle di Torre Annunziata (Tenore 1832, sub *Triticum lolioides*).

Characteristics of the plant community: pioneer heliophilous plant populations, very sparse, physiognomically characterized by perennial herbaceous plants (tentatively classified as "groupment with *Centranthus ruber* subsp. *ruber*"; Table 1) or shrubs (tentatively classified as "groupment with *Cytisus scoparius* subsp. *scoparius*"; Table 2), on pyroclastic slopes or lava flows produced by the 1944 eruption.

Main threats: 6.1, 8.1.2, 9.5.2.

OPHIOGLOSSUM LUSITANICUM L., Sp. Pl. 2: 1063 (1753) – Figure 2.

Life form: geophyta rhizomatosa.

Global distribution: Euri-Mediterranean-Subatlantic.

Italian distribution: Toscana, Lazio, Campania, Puglia, Calabria, Sicily, Sardinia.

Figure 1. Habit of *Festuca lachenalii* (C.C.Gmel.) Spenn. from Mt. Vesuvius (photo: Adriano Stinca).

Table 1. Vegetation relevés of perennial herbaceous plants communities from Mt. Vesuvius (groupment with *Centranthus ruber* (L.) DC. subsp. *ruber*) in which *Festuca lachenalii* (C.C.Gmel.) Spenn. was found.

Identification relevé code	1	2	3	4
East and North geographic coordinates (UTM WGS84, 33T)	451390, 4518910	451982, 4518811	452155, 518930	451788, 4520219
Date	22 June 2022	20 July 2021	20 July 2021	23 May 2016
Altitude (m a.s.l.)	1163	1141	1114	902
Aspect	SW	SE	ESE	NNE
Slope (°)	55	50	50	15
Area of relevé (m^2)	10	10	10	10
Stoniness (%)	100	100	100	20
Rockiness (%)	-	-	-	-
Vascular plant layer cover (%)	15	12	15	5
Moss and lichen layer cover (%)	-	-	-	80
Char. of all. *Linarion purpureae*, ord. *Scrophulario bicoloris-Helichrysetalia italici*, and cl. *Thlaspietea rotundifolii*				
Centranthus ruber (L.) DC. subsp. *ruber*	2	1	+	1
Artemisia campestris L. subsp. *variabilis* (Ten.) Greuter	+	2	2	-
Rumex scutatus L. subsp. *scutatus*	2	1	-	1
Scrophularia canina L.	-	+	+	-
Other species				
Trifolium arvense L. subsp. *arvense*	+	+	+	+
Festuca lachenalii (C.C.Gmel.) Spenn.	+	+	+	+
Festuca myuros L. subsp. *myuros*	+	+	+	+
Anisantha tectorum (L.) Nevski	+	+	1	-
Macrobriza maxima (L.) Tzvelev	+	+	1	-
Aira caryophyllea L.	+	+	+	-
Cerastium semidecandrum L.	+	+	+	-
Silene vulgaris (Moench) Garcke subsp. *tenoreana* (Colla) Soldano & F.Conti	+	+	+	-
Daucus carota L. subsp. *carota*	+	+	-	-
Centaurea deusta Ten. subsp. *deusta*	+	-	+	-
Picris hieracioides L. subsp. *hieracioides*	+	-	+	-
Trifolium pratense L. subsp. *pratense*	+	-	-	-
Arabis collina Ten. subsp. *collina*	+	-	-	-
Stereocaulon vesuvianum Pers. (lichen)	-	-	-	5

Figure 2. Habit of *Ophioglossum lusitanicum* L. from Mt. Vesuvius (photo: Adriano Stinca).

Table 2. Vegetation relevés of nanophanerophytic communities from Mt. Vesuvius (groupment with *Cytisus scoparius* (L.) Link subsp. *scoparius*) in which *Festuca lachenalii* (C.C.Gmel.) Spenn. was found.

Identification relevé code	1
East and North geographic coordinates (UTM WGS84, 33T)	452394, 4519236
Date	18 May 2015
Altitude (m a.s.l.)	1001
Aspect	E
Slope (°)	50
Area of relevé (m^2)	25
Stoniness (%)	85
Rockiness (%)	-
Vascular plant layer cover (%)	95
Moss and lichen layer cover (%)	15
Char. of ord. *Cytisetalia scopario-striati*, and cl. *Cytisetea scopario-striati*	
Cytisus scoparius (L.) Link subsp. *scoparius*	3
Transg. of all. *Linarion purpureae*	
Rumex scutatus L. subsp. *scutatus*	2
Centranthus ruber (L.) DC. subsp. *ruber*	2
Macrobriza maxima (L.) Tzvelev	2
Artemisia campestris L. subsp. *variabilis* (Ten.) Greuter	1
Anisantha sterilis (L.) Nevski	1
Scrophularia canina L.	+
Other species	
Silene vulgaris (Moench) Garcke subsp. *tenoreana* (Colla) Soldano & F.Conti	1
Robinia pseudoacacia L.	1
Festuca lachenalii (C.C.Gmel.) Spenn.	+
Anisantha tectorum (L.) Nevski	+
Aira caryophyllea L.	+
Cerastium semidecandrum L.	+
Arabidopsis thaliana (L.) Heynh.	+
Arabis collina Ten. subsp. *collina*	+
Pseudoturritis turrita (L.) Al-Shehbaz	+
Carduus pycnocephalus L. subsp. *pycnocephalus*	+
Crepis leontodontoides All.	+
Drabella muralis (L.) Fourr.	+
Geranium purpureum Vill.	+
Hypochaeris radicata L.	+
Myosotis ramosissima Rochel subsp. *ramosissima*	+
Picris hieracioides L. subsp. *hieracioides*	+
Sherardia arvensis L.	+
Sonchus asper (L.) Hill subsp. *asper*	+

Specimens: Ercolano tra la C. Cantoniera e l'Osservatorio Vesuviano, 481 m a.s.l., colata lavica del 1858, leg. et det. Adriano Stinca, 33T 448579-4519292, 07.12.2015 (IT); Ercolano tra la C. Cantoniera e l'Osservatorio Vesuviano, 501 m a.s.l., colata lavica del 1858, leg. et det. Adriano Stinca, 33T 448712-4519471, 19.03.2016 (IT); Ercolano tra la C. Cantoniera e l'Osservatorio Vesuviano, 501 m a.s.l., colata lavica del 1858, leg. et det. Adriano Stinca, 33T 448712-4519471, 09.11.2016 (IT).

Observation: Ercolano tra la C. Cantoniera e l'Osservatorio Vesuviano, 498 m a.s.l., colata lavica del 1858, obs. et det. Adriano Stinca, 33T 448701-4519521, 07.12.2015.

Previous reports: Portici, Torre del Greco e Torre dell'Annunziata (Tenore 1831a); Granatello di Portici (Pasquale 1869).

Characteristics of the plant community: heliophilous plant microcommunities, very dense, physiognomically characterized by perennial and annual herbaceous plants (Table 3), on lava flows produced by the 1858 eruption.

Main threats: 4.1, 6.1, 9.4, 9.5.2.

Based on the new data reported above, *F. lachenalii* is widespread on the Gran Cono Vesuviano, while *O. lusitanicum* is located exclusively on a lava flow in the western part of the volcano (Figure 3).

Discussion

According to the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2022b), "a taxon is presumed extinct in the wild when exhaustive surveys in known and / or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual". Accordingly, field investigations carried out locally and repeated over time are essential for the correct evaluation of the species and habitat conservation status. This is also true for those areas for which highly reliable studies on plant diversity are available, such as Mt. Vesuvius. In this volcanic area, the rediscovery of *F. lachenalii* and *O. lusitanicum*, both believed to be locally extinct (Ricciardi et al. 1988), should have implications for native biodiversity conservation policies and targets.

Festuca lachenalii is a generally rare microphyte within its global distribution range, which is also difficult to observe due to its short life cycle, concentrated in the spring-summer seasons. Therefore, its current distribution is very fragmented and is often updated. For example, in Europe it was recently found in Germany after more than a century (Eitel et al. 2007) and some new records for Serbia were indicated (Niketić et al. 2018) (Figure 4A). In Italy, *F. lachenalii* is a very rare species (Pignatti et al. 2017) and its presence has been confirmed in few regions (Bartolucci et al. 2018). It sometimes forms small therophytic meadows described as *Airo caryophylleae-Micropyretum tenelli* Brullo, Scelsi & Spampinato 2001, reported for the Aspromonte Massif (Brullo et al. 2001) and Elba Island (Foggi et al. 2006). In Campania it is reported only on the basis of historical data, for example by Tenore (1832) and Terracciano (1917, sub *Nardurus poa* Boiss. b. *ramosus* Parl. (sic!)). Therefore, my discoveries in the Vesuvian area confirm its occurrence in the entire region and further confirm the ancient discovery by Tenore (1832) for this volcanic area. On Mt. Vesuvius this annual plant grows between 716 and 1163 m of altitude, generally on the pyroclastic slopes within the pioneer plant communities characterized by *Centranthus ruber* subsp. *ruber*, *Rumex scutatus* subsp. *scutatus*, *Artemisia campestris* subsp. *variabilis*, *Trifolium arvense* subsp. *arvense*, *Festuca myuros* subsp. *myuros*, *Anisantha tectorum*, and *Macrobriza maxima* (Table 1). Less frequently it is found on lava flows mostly covered by lichens dominated by *Stereocaulon vesuvianum* (Table 1) and in nanophanerophytic communities dominated by *Cytisus scoparius* subsp. *scoparius* (Table 2). The syntaxonomic classification of the *F. lachenalii* coenoses detected, as well as the other types of vegetation occurring on Mt. Vesuvius, is in progress

Table 3. Vegetation relevés of communities from Mt. Vesuvius in which *Ophioglossum lusitanicum* L. was found (*Rumici bucephalophori-Ophioglossetum lusitanici* Médail, Pavon, Lo Cascio & Pasta 2016 subass. *trifolietosum scabri* Stinca, Perrino & Tomaselli 2022).

Identification relevé code	1*	2*	3*	4*	5*	6*	7	8	9
East and North geographic coordinates (UTM WGS84, 33T)	448579, 4519275	448574, 4519281	448573, 4519291	448558, 4519301	448549, 4519307	448531, 4519312	448541, 4519311	448529, 4519316	448712, 4519471
Date	19 March 2016	19 March 2016	19 March 2016	19 March 2016	19 March 2016	19 March 2016	19 March 2016	19 March 2016	19 March 2016
Altitude (m a.s.l.)	479	479	479	479	479	479	478	475	501
Aspect	-	WNW	N	-	-	-	-	-	-
Slope (°)	-	1	2	-	-	-	-	-	-
Area of relevé (m^2)	1.2	0.05	0.06	0.5	0.2	0.06	0.04	0.2	0.2
Stoniness (%)	-	-	-	-	-	-	-	-	-
Rockiness (%)	10	10	-	5	10	10	-	5	10
Vascular plant layer cover (%)	70	70	70	95	70	90	80	70	80
Moss layer cover (%)	90	90	100	10	90	70	70	70	90
Char. of subass. *trifolietosum scabri*									
Trifolium scabrum L.	1	1	1	+	1	-	+	1	+
Char. of ass. *Rumici bucephalophori-Ophioglossetum lusitanici*									
Ophioglossum lusitanicum L.	4	3	4	5	4	4	4	3	4
Rumex bucephalophorus L. s.l.	1	+	1	1	1	+	1	1	1
Char. of all. *Helianthemion guttati*, ord. *Helianthemetalia guttati*, and cl. *Helianthemetea guttati*									
Trifolium arvense L. subsp. *arvense*	+	+	+	+	+	2	1	1	2
Ornithopus compressus L.	+	-	1	-	+	1	-	1	-
Cerastium semidecandrum L.	+	-	+	-	+	+	+	+	+
Silene gallica L.	+	2	-	+	-	+	+	-	+
Aira caryophyllea L.	-	-	-	+	+	-	+	+	+
Lupinus angustifolius L.	-	+	-	+	1	-	-	+	-
Lagurus ovatus L.	-	+	-	-	-	-	+	+	-
Macrobriza maxima (L.) Tzvelev	-	-	+	-	+	-	-	-	+
Phedimus stellatus (L.) Raf.	1	+	-	+	-	-	-	-	-
Other species									
Petrorhagia saxifraga (L.) Link subsp. *gasparrinii* (Guss.) Pignatti ex Greuter & Burdet	+	+	+	+	-	-	-	+	+
Allium vineale L.	+	+	-	-	+	-	-	-	-
Daucus carota L. subsp. *carota*	+	+	-	-	-	-	+	-	-
Sixalix atropurpurea (L.) Greuter & Burdet	-	+	-	-	-	+	-	-	-
Muscari comosum (L.) Mill.	-	-	1	+	-	-	-	-	-
Reichardia picroides (L.) Roth	-	-	-	-	+	-	-	-	+
Echium plantagineum L.	-	-	-	-	-	2	-	-	-
Lathyrus clymenum L.	-	-	-	+	-	-	-	-	-

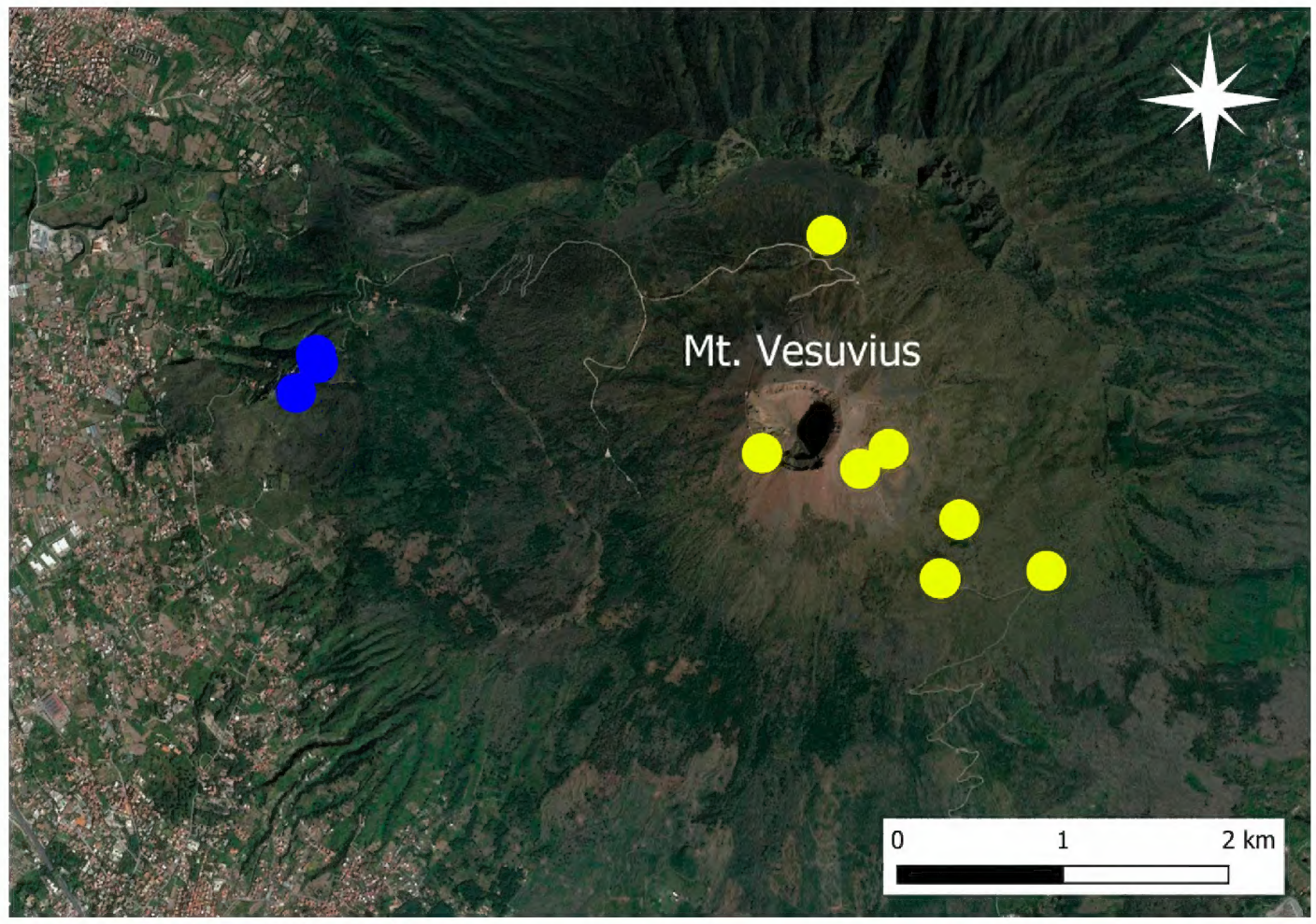

Figure 3. Distribution map of *Festuca lachenalii* (C.C.Gmel.) Spenn. (yellow circles) and *Ophioglossum lusitanicum* L. (blue circles) on Mt. Vesuvius.

and related results will be presented in a paper focusing on this research topic. In the current state of knowledge, I can propose only a provisional classification of communities from Mt. Vesuvius in which *F. lachenalii* was found: i) groupment with *Centranthus ruber* subsp. *ruber*, and ii) groupment with *Cytisus scoparius* subsp. *scoparius*. The first groupment can be ascribed to the alliance *Linarion purpureae* S. Brullo 1984, which includes several montane scree vegetation types of the southern Apennines and Sicily (Mucina et al. 2016). While the second groupment can be ascribed to the order *Cytisetalia scopario-striati* Rivas-Martínez 1975, which includes many western and central Mediterranean thermo- to supramediterranean and submediterranean broomy cytisoid scrubs (Mucina et al. 2016). Vesuvian plant communities can be ascribed to the habitat of community interest 8320 "Fields of lava and natural excavations" (Habitats Directive 92/43/EEC), in which *F. lachenalii* is a very rare species. Therefore, it does not seem to form real grasslands as reported by Brullo et al. (2001) and Foggi et al. (2006). In Italy, habitat 8320 is very localized and strictly linked to the volcanic districts occurring in Sicily and Campania, and marginally in Lazio and Toscana (Giusso del Galdo et al. 2016), with a total area of 168 km^2. In addition to Italy, it occurs also in Spain (Canary Islands), Portugal (mainland and Azores), and Greece (some Cyclades and Dodecanese Islands) (European Environment Agency 2022). As more than three-quarters of its total European surface area occurs in Italy, the latter has serious national responsibility for its conservation (Gigante et al. 2018). In Campania, it is known to occur on the island of Ischia and the Campi Flegrei, as well as Mt. Vesuvius (Figure 5A). In the latter location, in accordance with its variability related to the eruptive activities of the different volcanic systems (European Commission 2013), it includes lava fields, volcanic ash and lapilli fields, and fumaroles (Figures 5B, 5C, 5D). The Vesuvian *F. lachenalii* populations examined can be classified in the geosigmetum of the pioneer vegetation of Vesuvius (Filesi et al. 2010).

Since populations of this species occur mainly on the Gran Cono Vesuviano, one of Italy's most popular tourist destinations, the main threat is trampling by visitors (IUCN category: 6.1). Moreover, the Vesuvian pioneer plant communities, in addition to the natural evolutionary processes of vegetation, are subjected to the invasion of nitrogen-fixing alien species (Stinca et al. 2015), namely *Genista etnensis* (Raf.) DC. and *Robinia pseudoacacia* L. (IUCN category: 8.1.2). The negative effect on the vegetation of dust and pollutants originating from the passage of vehicles on paths and roads (De Micco et al. 2020) is also not negligible (IUCN category: 9.5.2). Finally, it is worth noting that in the study area this species reaches a higher altitude (i.e., 1163 m a.s.l.) than those reported in the literature for Italy, that is 950 m a.s.l. (Foggi et al. 2006) and 600 m a.s.l. (Pignatti et al. 2017).

Ophioglossum lusitanicum is a very small, inconspicuous, perennial fernlike species, with a strictly winter growing season. Therefore, also for this species, its precise area of distribution requires further investigation. To fill these knowledge gaps, in recent years some studies have been performed in Croatia (Brana et al. 2014), Algeria (Medjahdi et al. 2018), and Italy (Carta et al. 2008; Médail et al. 2016), which have expanded its known distribution (Figure 4B). In the Italian Peninsula it is considered a very rare species (Pignatti et al. 2017), reported only for the Tyrrhenian and Puglia regions (Bartolucci et al. 2018). In Campania, although reported in the past by several botanists (e.g., Tenore 1823, 1831b, 1835, Gussone 1855, Pasquale 1869, Terracciano 1872, Cerio and Bellini 1900, Béguinot 1905, Guadagno 1923, 1931), it has recently been confirmed only for two locations in the Sorrento Peninsula (Caputo et al. 1994) and Mt. Massico (De Natale et al. 2008), both sites characterized by calcareous soils. Similarly, for the Vesuvian area the only finds are from the 19th century by Tenore (1831a) and Pasquale (1869). During the field investigations, in 2015 I rediscovered this species on some lava flows produced by the 1958 eruption, that can be attributable to the habitat 8320 "Fields of lava

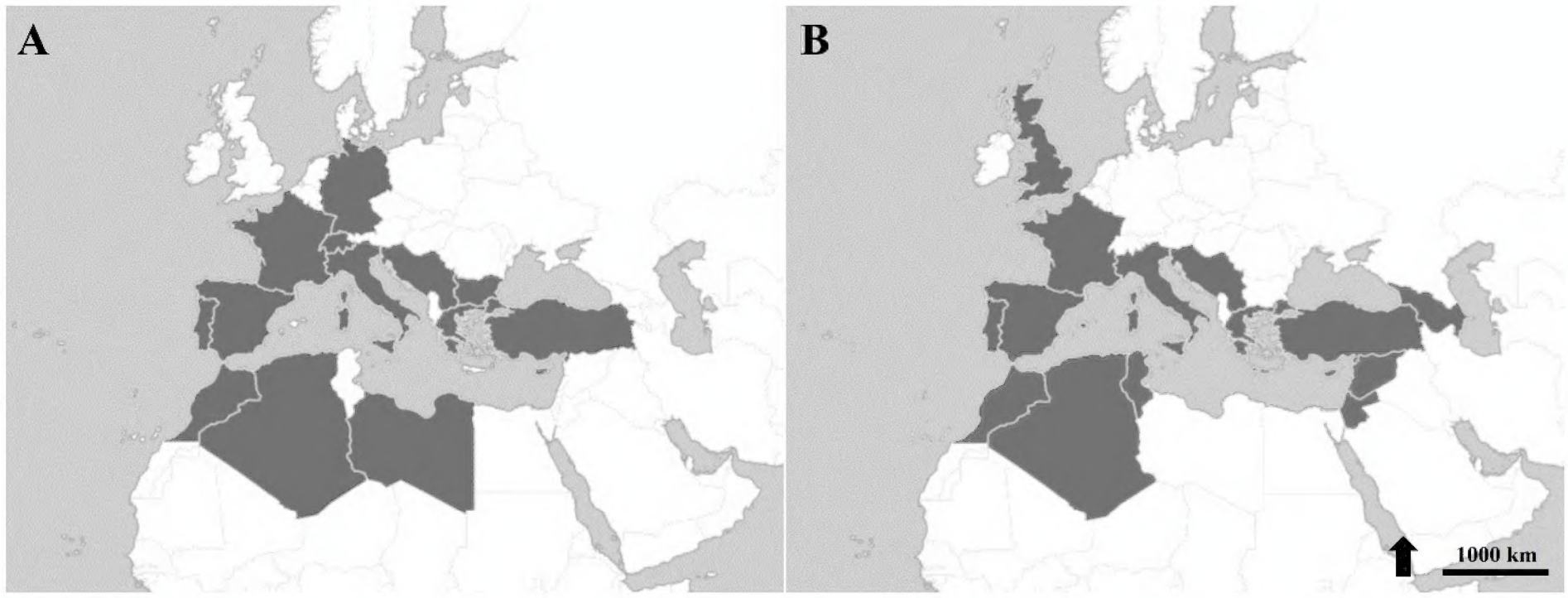

Figure 4. Global distribution map of *Festuca lachenalii* (C.C.Gmel.) Spenn. (A) and *Ophioglossum lusitanicum* L. (B) (from POWO 2022, modified).

and natural excavations" (Habitats Directive 92/43/EEC). A few years before my rediscovery, this site was affected by a severe wildfire that destroyed the previously established shrub vegetation. Therefore, it is possible that the induced fire disturbance favored this fern over the other coexisting species. In accordance with other authors (Brana et al. 2014), *O. lusitanicum* seems to prefer disturbed habitats in their early to middle successional stage. The plant microcommunities detected are characterized by a few vascular species such as *Rumex bucephalophorus* and *Trifolium scabrum*, in addition to some bryophytes which are indicators of substrate humidity (Table 3). These populations have been recently described as a new endemic subassociation from Mt. Vesuvius within the alliance *Helianthemion guttati* Br.-Bl. in Br.-Bl. et al. 1940: *Rumici bucephalophori-Ophioglossetum lusitanici* Médail, Pavon, Lo Cascio & Pasta 2016 subass. *trifolietosum scabri* Stinca, Perrino & Tomaselli 2022 (Perrino et al. 2022). The latter authors also hypothesized the attribution of these plant communities to the priority habitat 6220* (Pseudo-steppe with grasses and annuals (*Thero-Brachypodietea*)). However, further studies on the vegetation of the lava flows of Mt. Vesuvius are needed, also considering the large variety of micro-environments that can be identified in them. Due to the small area of such communities, some transgressive species of the *Festuco valesiacae-Brometea erecti* Br.-Bl. & Tüxen ex Br.-Bl. 1949 (e.g., *Petrorhagia saxifraga* subsp. *gasparrinii*, *Allium vineale*, *Sixalix atropurpurea*, and *Muscari comosum*), *Echio-Galactition tomentosae* O.De Bolòs et Molinier 1969 (e.g., *Echium plantagineum*), and *Lygeo sparti-Stipetea tenacissimae* Rivas-Martínez 1978 (e.g., *Daucus carota* subsp. *carota*, *Lathyrus clymenum*, and *Reichardia picroides*) were reported. In accordance with Filesi et al. (2010), this endemic subassociation can be classified in the geosigmetum of the pioneer vegetation of Vesuvius.

The discovered populations are located on the edge of the only public road that leads to the summit of Mt. Vesuvius, near some restaurants. Consequently, the main threats consist in road widening (IUCN category: 4.1), trampling by people (IUCN category: 6.1), accumulation of pollutants (IUCN category: 9.5.2), and illegal dumping of waste (IUCN category: 9.4). However, competition between species triggered by successional vegetation processes may also be a threat to the conservation of this fernlike plant on Mt. Vesuvius.

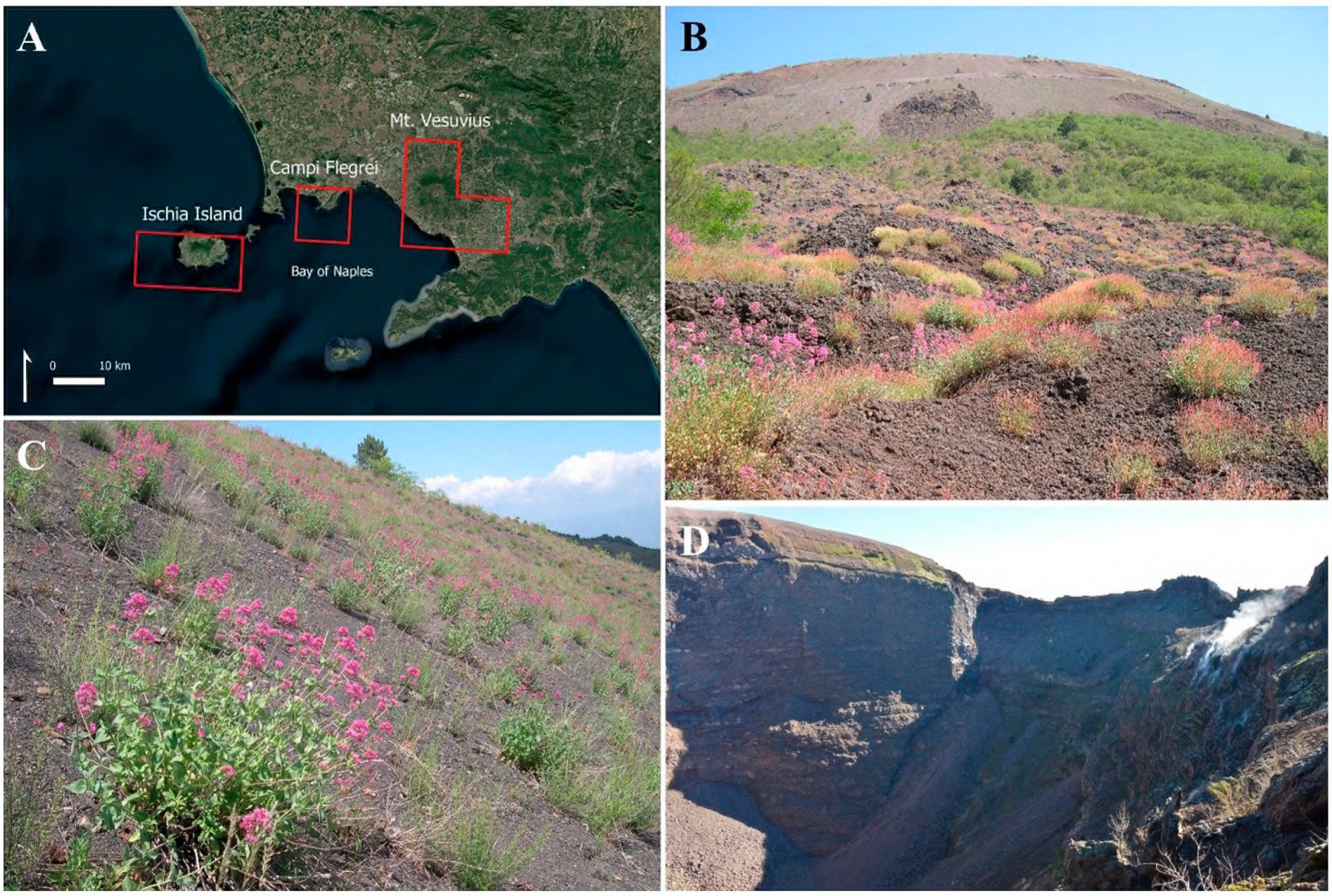

Figure 5. Distribution in Campania of habitat 8320 on the basis of the cells reported in the 4th Habitat report ex-Art. 17 (period 2013-2018; Eionet 2019) (A), with some aspect identified on Mt. Vesuvius: *Rumex scutatus* communities on lava flows produced by the 1944 eruption (B), *Centranthus ruber* communities on pyroclastites produced by the 1944 eruption (C), fumaroles located within the Gran Cono Vesuviano (D) (photos: Adriano Stinca).

Conclusions

Plant diversity of active volcanic areas is highly characterized and strongly affected by eruptive phenomena which periodically trigger new processes of primary plant succession. In such areas, where the extinction of species by natural causes is a possible event, exhaustive knowledge of the flora represents the first step towards its conservation. Therefore, the rediscovery in the Vesuvian area of *F. lachenalii* and *O. lusitanicum*, after about 200 and 150 years respectively, allows confirmation of the presence of these rare species for the local flora and can help activate indispensable protection measures by the Vesuvius National Park Authority, since both species are currently subject to many anthropogenic threats. Their preservation will also contribute to protect the delicate habitat of community interest in which they occur.

Syntaxonomic scheme

THLASPIETEA ROTUNDIFOLII Br.-Bl. 1948
SCROPHULARIO BICOLORIS-HELICHRYSETALIA ITALICI Brullo 1984
Linarion purpureae S. Brullo 1984
Groupment with *Centranthus ruber* subsp. *ruber*

CYTISETEA SCOPARIO-STRIATI Rivas-Martínez 1975
CYTISETALIA SCOPARIO-STRIATI Rivas-Martínez 1975
Groupment with *Cytisus scoparius* subsp. *scoparius*

HELIANTHEMETEA GUTTATI Rivas Goday and Rivas-Martínez 1963
HELIANTHEMETALIA GUTTATI Br.-Bl. in Br.-Bl. et al. 1940
Helianthemion guttati Br.-Bl. in Br.-Bl. et al. 1940
Rumici bucephalophori-Ophioglossetum lusitanici Médail, Pavon, Lo Cascio & Pasta 2016
trifolietosum scabri Stinca, Perrino & Tomaselli 2022

Acknowledgements

The author thank the anonymous reviewers and the subject editor for their constructive comments to the manuscript as well as the Vesuvius National Park Authority for granting the authorizations for the collection of the plant materials.

Bibliography

Agostini R (1975) Vegetazione pioniera del Monte Vesuvio: aspetti fitosociologici ed evolutivi. Arch. Bot. Biogeogr. Ital. 51: 11–34.

Baillie C-K, Kaufholdt D, Meinen R, Hu B, Rennenberg H, Hänsch R, Bloem E (2018) Surviving Volcanic Environments-Interaction of Soil Mineral Content and Plant Element Composition. Front. Environ. Sci. 6: 52. https://doi.org/10.3389/fenvs.2018.00052

Bartolucci F, Peruzzi L, Galasso G, Albano A, Alessandrini A, Ardenghi NMG, Astuti G, Bacchetta G, Ballelli S, Banfi E et al. (2018) An updated checklist of the vascular flora native to Italy. Plant Biosyst. 152: 179–303. https://doi.org/10.1080/11263504.2017.1419996

Béguinot A (1905) Appunti per una flora dell'Isola di Capri. Bull. Soc. Bot. Ital. 1–2: 42–53.

Bonari G, Fantinato E, Lazzaro L, Sperandii MG, Acosta ATR, Allegrezza M, Assini S, Caccianiga M, Di Cecco V, Frattaroli A et al. (2021) Shedding light on typical species: implications for habitat monitoring. Plant Sociol. 58: 157–166. https://doi.org/10.3897/pls2020581/08

Brana S, Vuković N, Kaligarič M (2014) Least adder's-tongue (*Ophioglossum lusitanicum* L.) in Croatia - distribution, ecology and conservation. Acta Bot. Croat. 73: 471–480. https://doi.org/10.2478/botcro-2014-0015

Braun-Blanquet J (1932) Plant Sociology: The Study of Plant Communities. McGraw-Hill: New York, USA.

Brullo S, Scelsi F, Spampinato G. (2001) La vegetazione dell'Aspromonte. Studio fitosociologico. Laruffa editore, Reggio Calabria, Italy.

Caputo G, La Valva V, Nazzaro R, Ricciardi M (1994) La flora della Penisola Sorrentina (Campania). Delpinoa, n.s. 31–32 (1989-1990): 3–97.

Carta A, Pierini B, Peruzzi L (2008) Distribuzione di *Ophioglossum lusitanicum* L. (Psilotopsida) in Toscana. Inform. Bot. Ital. 40: 135–141.

Cerio I, Bellini R (1900) Flora dell'Isola di Capri. Emilio Prass: Napoli, Italy.

Conti F, Ciaschetti G, Di Martino L., Bartolucci F (2019) An annotated checklist of the vascular flora of Majella National Park (Central Italy). Phytotaxa 412: 1–90. https://doi.org/10.11646/phytotaxa.412.1.1

De Micco V, Amitrano C, Stinca A, Izzo LG, Zalloni E, Balzano A, Barile R, Conti P, Arena C (2020) Dust accumulation due to anthropogenic impact induces anatomical and photochemical changes in leaves of *Centranthus ruber* growing on the slope of the Vesuvius volcano. Plant Biol. 22(S1): 93–102. https://doi.org/10.1111/plb.12966

De Natale A, Di Nuzzo F, Crescenzi E (2008) Note Floristiche per la Penisola Sorrentina, il Massiccio del Matese e specie notevoli per la Campania. Inform. Bot. Ital. 40: 243-248.

Eionet (2019) Eionet Central Data Reporitory. Available online: https://cdr.eionet.europa.eu/it/eu/art17/envxuwp6g/ (accessed on 26 December 2022).

Eitel M, Treiber G, Welss W (2007) Der Kies-Dünnschwingel (Micropyrum tenellum (L.) Link, Poaceae) nach über 100 Jahren wieder in Deutschland und neu für Bayern. RegnitzFlora 1: 31-34.

European Commission (2013). Interpretation Manual of European Union Habitats. EUR 28. April 2013. DG Environment, Nature ENV B.3. Available online: https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf (accessed on 26 December 2022).

European Environment Agency (2022) Fields of lava and natural excavations. Available online: https://eunis.eea.europa.eu/habitats/10171#sites (accessed on 26 December 2022).

Filesi L, Rosati L, Paura B, Cutini M, Strumia S, Blasi C. (2010) Le serie di vegetazione della regione Campania. In: Blasi C (Ed) La Vegetazione d'Italia con Carta delle Serie di Vegetazione in scala 1:500.000. Palombi & Partner S.r.l.: Roma, Italy, pp. 351–374.

Foggi B, Cartei L, Pignotti L, Signorini MA, Viciani D, Dell'Olmo L, Menicagli E (2006) Il paesaggio vegetale dell'Isola d'Elba (Arcipelago Toscano). Studio fitosociologico e cartografico. Fitosociologia 43: 3–95.

Galasso G, Conti F, Peruzzi L, Ardenghi NMG, Banfi E, Celesti-Grapow L, Albano A, Alessandrini A, Bacchetta G, Ballelli S et al. (2018) An updated checklist of the vascular flora alien to Italy. Plant Biosyst. 152: 556–592. https://doi.org/10.1080/11263504.2018.1441197

Gigante D, Acosta ATR, Agrillo E, Armiraglio S, Assini S, Attorre F, Bagella S, Buffa G, Casella L, Giancola C et al. (2018) Habitat conservation in Italy: the state of the art in the light of the first European Red List of Terrestrial and Freshwater Habitats. Rend. Fis. Acc. Lincei 29: 251–265. https://doi.org/10.1007/s12210-018-0688-5

Giusso del Galdo G, Laureti L, Puglisi M, Ravera S, Strumia S (2016) 8320 Campi di lava e cavità naturali. In: Angelini P, Casella L, Grignetti A, Genovesi P (Eds) Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE) in Italia: habitat: 194–195. ISPRA, Serie Manuali e linee guida, 142/2016: Roma, Italy, 2016.

Guadagno M (1923) La vegetazione del M. Nuovo e le sue origini. Boll. Soc. Nat. Napoli 34 (1921–1922): 238–306.

Guadagno M (1931) Flora Caprearum Nova. Arch. Bot. 7: 7–38, 145–176, 244–275.

Gussone G (1855) Enumeratio Plantarum Vascularium in Insula Inarime sponte provenientium vel oeconomico usu passim cultarum: 395. Ex Vanni Typographeo: Neapoli, Italy. https://doi.org/10.5962/bhl.title.9946

IUCN (2022a) Threats Classification Scheme (Version 3.2). Available online: https://www.iucnredlist.org/resources/threat-classification-scheme (accessed on 20 November 2022).

IUCN (2022b) Guidelines for Using the IUCN Red List Categories and Criteria (Version 15.1). Available online: https://www.iucnredlist.org/resources/redlistguidelines (accessed on 20 November 2022).

Mazzoleni S, Ricciardi M (1993) Primary succession on the cone of Vesuvius. In: Miles J, Walton DWH (Eds) Primary Succession on Land. Special Publication Number 12 of the British Ecological Society: 101-112. Oxford: Blackwell Scientific Publications, 1993.

Mazzoleni S, Ricciardi M, Aprile GA (1989) Aspetti pionieri della vegetazione del Vesuvio. Ann. Bot., Studi Territ. 47(Suppl. 6): 97–110.

Médail F, Pavon D, Lo Cascio P, Pasta S (2016) Sulla presenza di *Ophioglossum lusitanicum* L. (Psilotopsida) nell'isola di Vulcano e aggiunte alla flora vascolare delle Isole Eolie (Sicilia nord-orientale). Nat. Sicil., Ser. 4, 40: 51–66.

Medjahdi B, Letreuch-Belrouci A, Babali I (2018) Une Nouvelle station d'*Ophioglossum lusitanicum* L. en Oranie (Algerie Occidentale). Acta Bot Malacit. 42: 177–179. https://doi.org/10.24310/abm.v42i1.3297

Mucina L, Bültmann H, Dierßen K, Theurillat J-P, Raus T, Čarni A, Šumberová K, et al. (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl. Veg. Sci. 19: 3–264. https://doi.org/10.1111/avsc.12257

Musarella CM, Brullo S, del Galdo GG (2020) Contribution to the Orophilous Cushion-Like Vegetation of Central-Southern and Insular Greece. Plants 9: 1678. https://doi.org/10.3390/plants9121678

Niketić M, Tomović G, Perić R, Zlatković B, Anačkov G, Đorđević V, Jogan N, Radak B, Duraki Š, Stanković M, Kuzmanović N Lakušić D Stevanović V (2018) Material on the annotated checklist of vascular flora of Serbia: Nomenclatural, taxonomic and floristic notes I. Bull. Nat. Hist. Mus. 11: 101–180. https://doi.org/10.5937/bnhmb2013087N

Pasquale GA (1869) Flora vesuviana o catalogo ragionato delle piante del Vesuvio confrontate con quelle dell'isola di Capri e di altri luoghi circostanti. Atti R. Accad. Sc. Fis. e Mat. Napoli 4: 1–142.

Perrino EV, Tomaselli V, Wagensommer RP, Silletti GN, Esposito A, Stinca A (2022) Ophioglossum lusitanicum L.: New Records of Plant Community and 92/43/EEC Habitat in Italy. Agronomy 12: 3188. https://doi.org/10.3390/agronomy12123188

PFI (2022) Portale della Flora d'Italia/Portal to the Flora of Italy. Available online: http://dryades.units.it/floritaly/index.php (accessed on 15 November 2022).

Pignatti S, Guarino R, La Rosa M (2017) Flora d'Italia 1; Edagricole: Bologna, Italy.

Pignatti S, Guarino R, La Rosa M (2019) Flora d'Italia 4; Edagricole: Bologna, Italy.

POWO (2022) Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available online: https://powo.science.kew.org/ (accessed on 15 November 2022).

Ricciardi M, Aprile GG, La Valva V, Caputo G (1988) La Flora del Somma-Vesuvio. Boll. Soc. Nat. Napoli 96 (1986): 3–121.

Ricciardi M, Motti R, Stinca A (2016) Flora illustrata del Vesuvio. Storia, paesaggi, vegetazione. Doppiavoce: Napoli, Italy.

Rothmaler W, Akeroid JR (1993) *Ophioglossum* L. In: Tutin TG, Burges NA, Chater AO, Edmondson JR, Heywood VH, Moore DM, Valentine DH, Walters SM, Webb DA (Eds) Flora Europaea 1, 2nd ed. Cambridge University Press: Cambridge, UK, 1993, pp. 9-10.

Stace CA (1980) Micropyrum Link. In: Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA (Eds) Flora Europaea 5. Cambridge University Press: Cambridge, UK, p. 157.

Stinca A (2017) *Orchis italica* Poir. (*Orchidaceae*): rediscovery after four centuries of a presumably extinct species in Mt. Vesuvius, Italy. Ann. Bot. 7: 71-74. https://doi.org/10.4462/annbotrm-13294

Stinca A (2020) *Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Sweet (Solanaceae): an alien species new to continental Europe. BioInvasions Rec. 9: 660-669. https://doi.org/10.3391/bir.2020.9.4.01

Stinca A (2022) Biodiversity and Conservation of Vascular Flora: A Challenge for the Survival of Humans on Earth. Diversity 14: 720. https://doi.org/10.3390/d14090720

Stinca A, Motti R (2009) The vascular flora of the Royal Park of Portici (Naples, Italy). Webbia 64: 235-266. https://doi.org/10.1080/00837792.2009.10670861

Stinca A, Motti R (2013) Aggiornamenti floristici per il Somma-Vesuvio e l'Isola di Capri. Inform. Bot. Ital. 45: 35–43.

Stinca A, Motti R, Ricciardi M (2009) Aspetti di vegetazione primaria del Vesuvio (Napoli, Italia). Riassunti 104° Congresso della Società Botanica Italiana, Campobasso: 299.

Stinca A, D'Auria G, Motti R (2012a) Integrazioni alla flora vascolare aliena della Campania (Sud Italia). Inform. Bot. Ital. 44: 287–293.

Stinca A, D'Auria G, Motti R (2012b) Sullo status invasivo di *Bidens bipinnata*, *Phoenix canariensis*, *Pistia stratiotes* e *Tradescantia fluminensis* in Campania (Sud Italia). Inform. Bot. Ital. 44: 295–299.

Stinca A, D'Auria G, Salerno G, Motti R (2013) Ulteriori integrazioni alla flora vascolare aliena della Campania (Sud Italia). Inform. Bot. Ital. 45: 71–81.

Stinca A, D'Auria G, Motti R (2014) Manihot esculenta (Euphorbiaceae), a new alien species in Italy. Hacquetia 13: 355–357. https://doi.org/10.2478/hacq-2014-0011

Stinca A, Chirico GB, Incerti G, Bonanomi G (2015) Regime Shift by an Exotic Nitrogen-Fixing Shrub Mediates Plant Facilitation in Primary Succession. PLoS ONE 10: e0123128. https://doi.org/10.1371/journal.pone.0123128

Stinca A, Musarella CM, Rosati L, Laface VLA, Licht W, Fanfarillo E, Wagensommer RP, Galasso G, Fascetti S, Esposito A et al. (2021) Italian Vascular Flora: New Findings, Updates and Exploration of Floristic Similarities between Regions. Diversity 13: 600. https://doi.org/10.3390/d13110600

Tavilla G, Angiolini C, Bagella S, Bonini F, Cambria S, Caria MC, Esposito A, Fanfarillo E, Ferri V, Fiaschi T et al. (2022) New national and regional Annex I Habitat records: from #37 to #44. Plant Sociol. 59: 49-66. https://doi.org/10.3897/pls2022591/05

Tenore M (1823) Flora medica universale e flora particolare della provincia di Napoli. In: Tenore M. (Ed) Corso delle Botaniche Lezioni. Ed. Tipografia del Giornale Enciclopedico: Napoli, Italy.

Tenore M (1831a) Sylloge plantarum vascularium Florae Neapolitanae hucusque detectarum. Addenda et emanda altera. Tipografia del Fibreno: Napoli, Italy, p. 577.

Tenore M (1831b) Sylloge plantarum vascularium Florae neapolitanae hucusque detectarum. Tipografia del Fibreno, Napoli, Italy, p. 485.

Tenore M (1832) Memoria delle peregrinazioni botaniche, effettuate nella provincia di Napoli nella primavera del 1825 dal Cavaliere Michele Tenore colle indicazioni di alcune piante da aggiungersi alla Flora Napolitana e la descrizione di una nuova specie di *Ononis*. Atti R. Accad. Sc. Cl. Fis. e St. Nat. 3: 66–98.

Tenore M (1835) Flora Napolitana 5. Dalla Stamperia e Cartiera del Fibreno: Napoli, Italy, pp. 301–302.

Terracciano N (1872) Relazione intorno alle peregrinazioni botaniche fatte per disposizione della Deputazione Provinciale di Terra di Lavoro in certi luoghi della provincia dal Dottor N. Terracciano. Caserta: Nobile e C., p. 240.

Terrracciano N (1917) Aggiunta alla Flora dei Campi Flegrei. Atti R. Ist. Incoragg. Napoli., Ser. 6 68 (1916): 271–454.

Thiers B (2022) Index Herbariorum: A Global Directory of Public Herbaria. New York Botanical Garden's Virtual Herbarium. Available online: http://sweetgum.nybg.org/ih/ (accessed on 30 September 2022).